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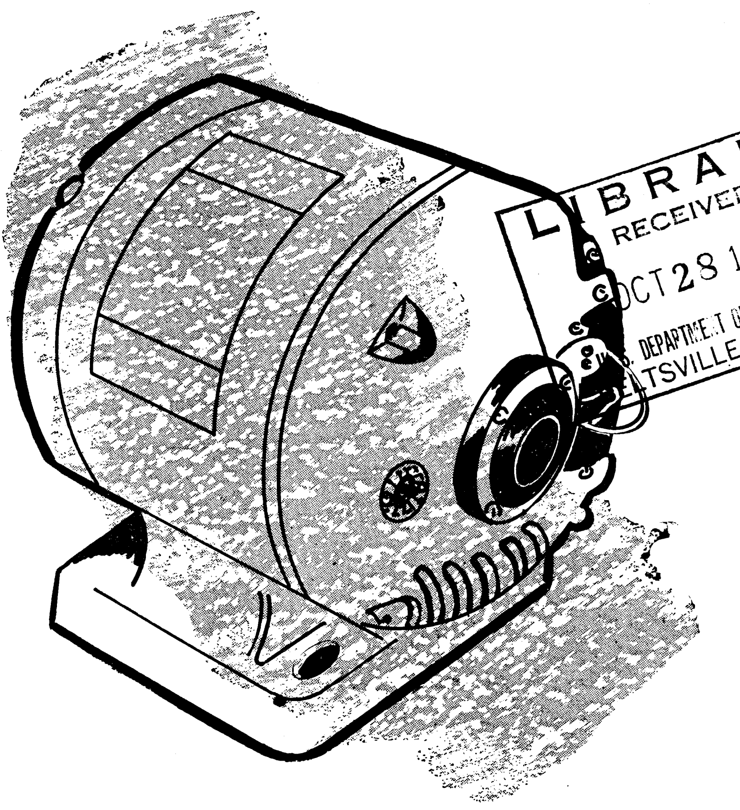
SINGLE-PHASE ELECTRIC MOTORS

For Farm Use



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CONTENTS

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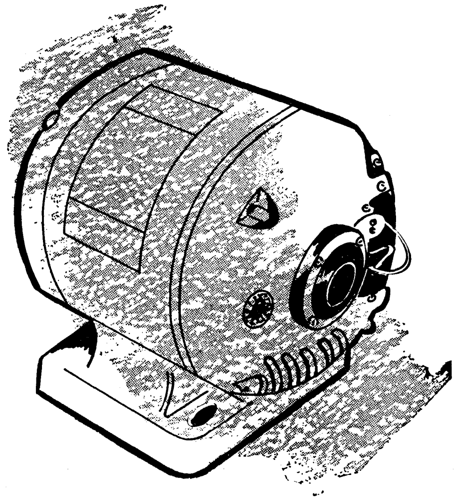

SINGLE-PHASE ELECTRIC MOTORS

For Farm Use

By H. B. Puckett, Agricultural Engineer, Agricultural Engineering Research Division, Agricultural Research Service

An electric motor is an efficient, compact, and dependable source of power.

Effective use of a motor requires selection of the proper type for the job, proper installation, and use of suitable controls for operation and protection of the motor.

Alternating-current motors designed to operate on 60 cycles, 120 or 240 volts, single-phase service are the type in general use on farms.

Special-purpose motors installed by equipment manufacturers as an integral part of the equipment usually have particular characteristics and are not suitable for general-purpose use.

TYPES OF SINGLE-PHASE A.C. MOTORS

Single-phase, alternating-current motors divide into five general types:

1. Split phase.
2. Capacitor start-induction run.
3. Capacitor start-capacitor run (two-value capacitor).
4. Repulsion-induction.
5. Series, or universal.

The motors differ primarily in starting torque developed and starting current required. The type to use will depend on the starting requirements of the equipment to be driven.

Table 1 lists the important characteristics of each type of motor.

Split-Phase Motor

Split-phase motors (fig. 1) are inexpensive, simply constructed, and suitable for easy starting loads such as ventilating fans. The motors are electrically reversible—direction of rotation can be changed by reversing the line connections to the auxiliary, or starting, winding. They are designed to operate on either 115 or 230 volts, but not on both.

TABLE 1.—*General-purpose single-phase motor types and their characteristics*

Type	Horsepower ranges	Load-starting ability	Starting current	Characteristics	Electrically reversible	Typical uses
Split-phase	1/20 to 1/3	Easy starting loads. Develop 150% full-load torque.	High, 5 to 7 times full-load current.	Inexpensive, simple construction; small for a given motor power; nearly constant speed with varying load.	Yes	Fan, centrifugal pump; a load that increases as speed increases.
Capacitor start-induction run.	1/8 to 10	Hard starting loads. Develop 300% of full-load torque.	Medium, 3 to 6 times full-load current.	Simple construction; long service; good general-purpose motor suitable for most applications; nearly constant speed with varying load.	Yes	Reciprocating compressor, auger conveyor, vacuum pump. (Specially designed capacitor motors are suitable for silo unloaders and barn cleaners.)
Capacitor start-capacitor run.	1/2 to 20	Hard starting loads. Develop 350% of full-load torque.	Medium, 3 to 5 times full-load current.	Simple construction; long service with minimum maintenance; requires more space to accommodate larger capacitor; low line current; nearly constant speed with varying load.	Yes	Conveyor, barn cleaner, elevator, silo unloader.
Repulsion	1/6 to 10	Very hard starting loads. Develop 350 to 400% of full-load torque.	Low, 2 to 4 times full-load current.	Larger than equivalent size split-phase or capacitor motors; requires more maintenance because of brush wear; running current varies only slightly with load.	No—the usual method of reversing the direction of rotation is by brush-ring adjustment.	Conveyor, drag, burr mill, deep-well pump, hoist, silo unloader, bucket elevator.
Series, or universal	1/150 to 1	Hard starting loads. Develop 350 to 450% of full-load torque.	High	High speed; small size for a given horsepower; usually directly connected to load; speed varies with variations in load.	Yes—some types	Portable tools for the shop and kitchen appliances for the home.

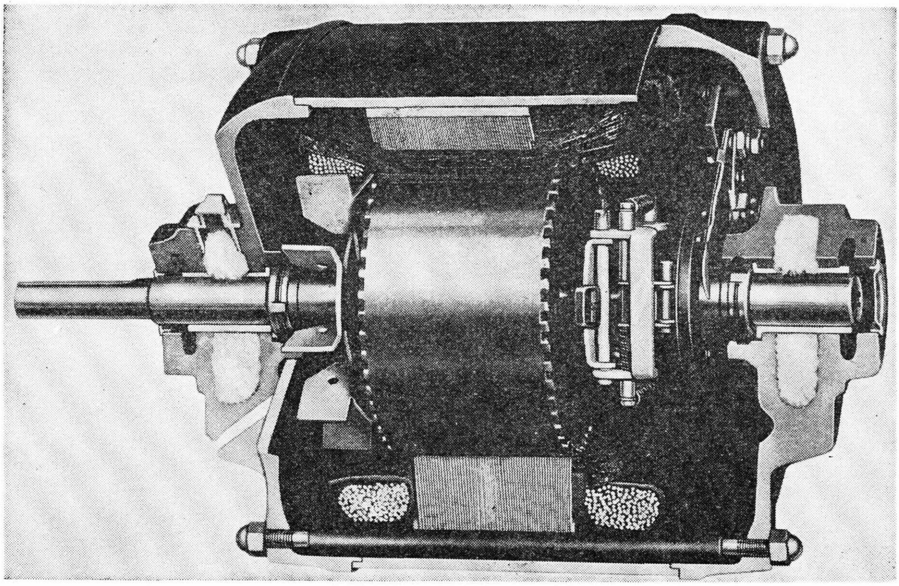

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FIGURE 1.—The split-phase motor is a simple low-cost motor for easy starting loads.

Capacitor Start-Induction Run Motor

Capacitor start-induction run motors (fig. 2) are similar in design to split-phase motors with one important difference—a capacitor is placed in series with the auxiliary winding. The capacitor gives the motor greater starting torque at less current draw than split-phase motors of equal size. The capacitor start-induction run motor is electrically reversible in the same manner as a split-phase motor—line connections to the starting winding are interchanged.

The starting torque of capacitor motors may be reduced when operating at very low temperatures because the capacitance of the electrolytic capacitor is less at low temperature.

These motors are the most popular type for general use.

Capacitor Start-Capacitor Run Motor

Capacitor start-capacitor run motors (fig. 3) are similar to the capacitor start-induction run motors. They use the same type of starting circuit, but a small capacitor remains in series with the auxiliary winding during the running operation. This capacitor gives more efficient operation by lowering the line current required to energize the motor.

These motors have slightly higher starting torque than capacitor start-induction run motors and can handle more difficult starting loads. Starting current requirement is about the same for both types.

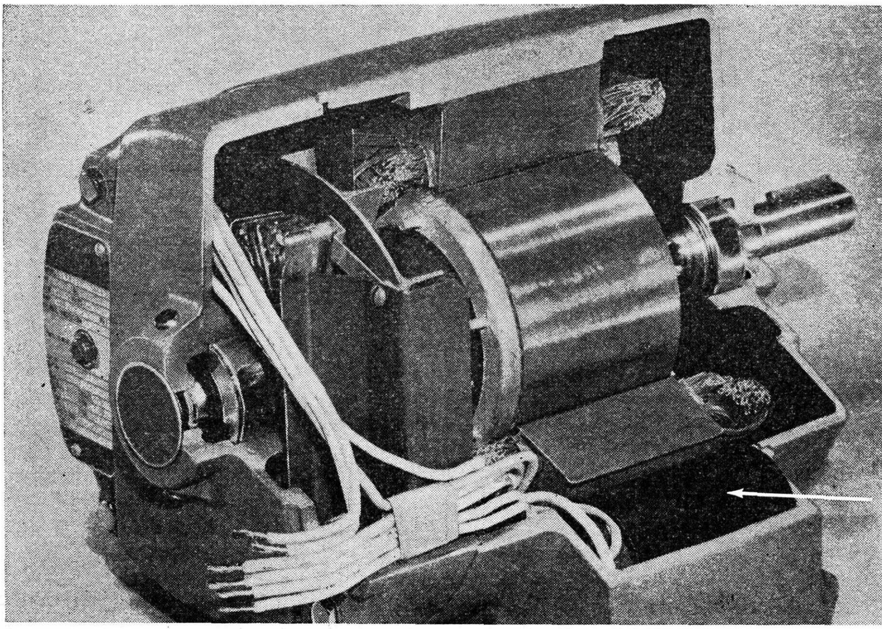

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FIGURE 2.—The capacitor start-induction run motor has medium starting torque and is one of the most used general-purpose motors. Arrow points to capacitor.

The motors are simple in construction, require little maintenance, and the direction of rotation can be electrically reversed.

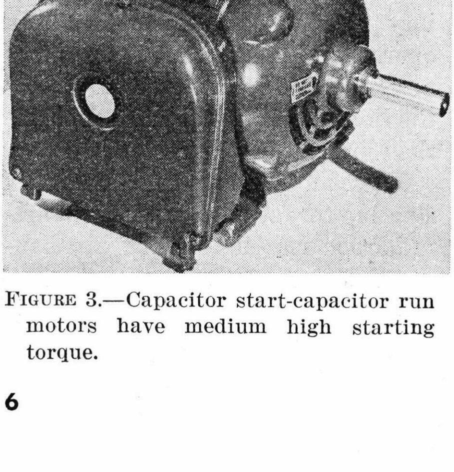

FIGURE 3.—Capacitor start-capacitor run motors have medium high starting torque.

Repulsion Motor

The repulsion-induction motor (fig. 4) is one of the three major variations of the repulsion-type motor. The other two are the repulsion start-induction run and the repulsion. A characteristic of repulsion motors is that running current varies very little with variations in load. The motors are more expensive than split-phase or capacitor motors and require more maintenance because of brush and commutator wear.

(*a*) *Repulsion-induction motors* are capable of starting very heavy loads. The rotor has two windings, a wound rotor (similar to a d.c. generator or motor) and a squirrel cage. The brushes do not lift. It is capable of starting very difficult

loads under lower voltage than other general-purpose motors.

(*b*) *The repulsion start-induction run motor* can also handle very heavy starting loads and has constant speed characteristics. This type starts as a repulsion and then operates as an induction motor similar to the split-phase or capacitor start motor.

(*c*) *The repulsion motor* is sometimes referred to as a variable-speed motor. Speed of this motor is controlled by the load. The repulsion motor starts and runs as a repulsion motor. The brushes do not lift and the commutator is not shorted. The output torque and its speed with a given load is controlled by the brush setting. The no-load speed of this motor is above synchronous speed. (Synchronous speed for a 4-pole induction motor on 60-cycle current would be 1,800 r.p.m.)

Series, or Universal, Motor

The series, or universal, motor is a high-speed motor that will operate on either alternating current or direct current. It is usually a special-purpose motor and an integral part of portable equipment such as drills, grinders, sanders, sprayers, vacuum cleaners, and food mixers.

Advantages of this type of motor include high starting torque, high-power-to-size ratio, and rapid acceleration of the load to speed.

Operating speed of these motors

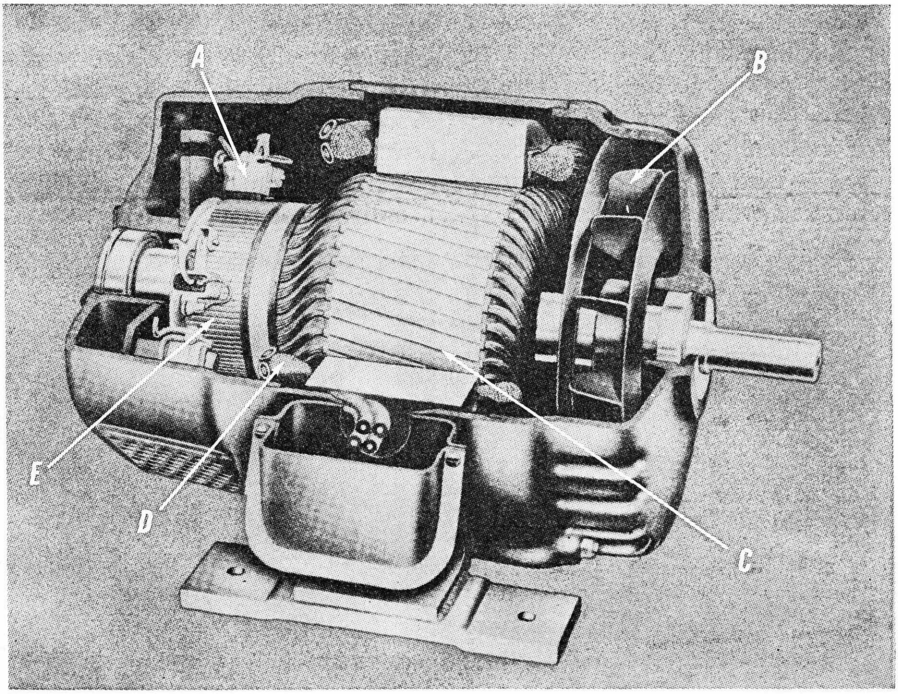

FIGURE 4.—Repulsion-induction motors have high starting torque and low starting current. They require more maintenance because of brush wear. *A*, Brush ring and brushes; *B*, ventilating fan; *C*, wound rotor; *D*, main windings; *E*, commutator.

depends on the load. They do not operate at a constant speed, but run as fast as the load permits. If not loaded, they will overspeed, which may damage the motor.

SELECTION OF MOTOR

Selection of the electric motor depends primarily on the type of electric power available, type and size of the load, and conditions under which the motor will operate.

Power Available

Farm electric service usually is single-phase, 60-cycle, 120/240-volt alternating current. Single-phase motors up to and including ½-horsepower size usually may be operated on 120 volts. Larger motors should be operated on 240 volts.

Some farms may have three-phase electric power available. Three-phase power is best for motor operation, especially for larger motors. Three-phase, general-purpose motors are available and are less expensive than single-phase motors in the 1-horsepower and larger sizes.

Load

Farm equipment varies widely in the amount of power required for starting. For example, fans, bench saws, and grindstones are easy to start. Split-phase motors, which have low starting torque, would satisfactorily operate such equipment. Some equipment, such as reciprocating compressors, auger conveyors, and vacuum pumps, are harder to start and require motors with higher starting torque, such as the capacitor start-induction run motor. Other equipment, such as bucket elevators, barn cleaners, or silo unloaders are hard to start and require motors with high starting torque, such as capacitor start-capacitor run or repulsion-induction motors. Specially designed capacitor motors are suitable for heavy or hard-to-start loads.

Farm-equipment manufacturers usually recommend the type and

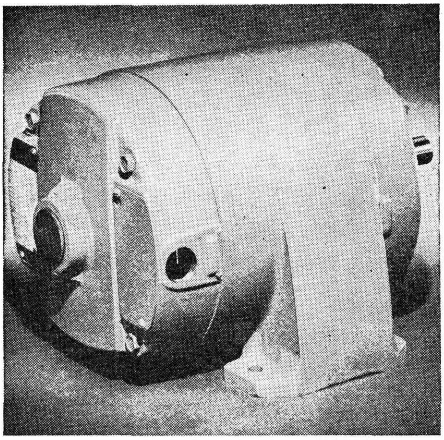

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FIGURE 5.—Drip-proof (left) and splash-proof (right) motors draw cooling air through the motor windings. The splash-proof motor has greater protection against the entry of splashing liquids.

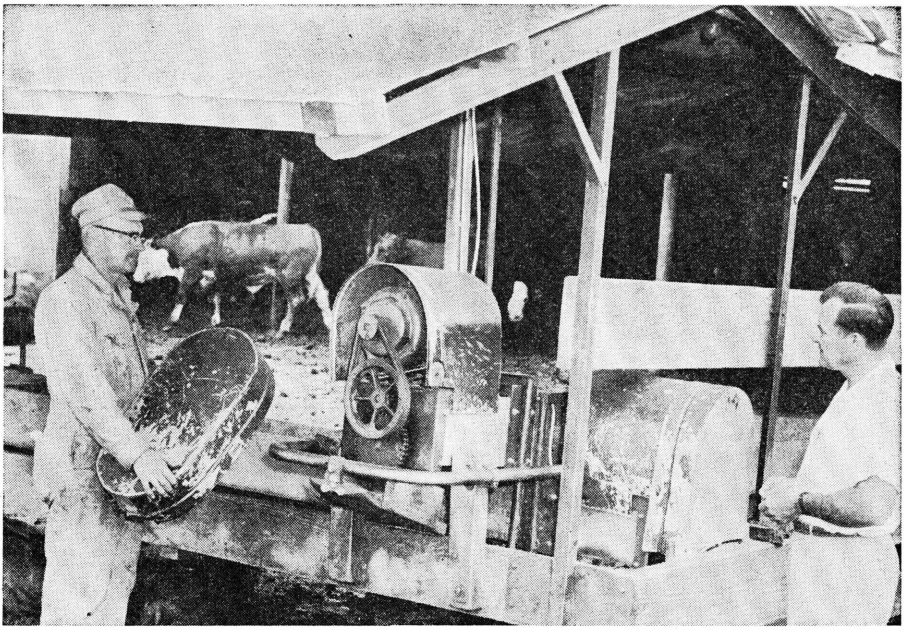

FIGURE 6.—Open-type motors that are installed outside should be protected from the weather by a suitable covering. The motor drive is covered as a safety precaution.

size of electric motor needed to operate their equipment.

Operating Conditions

Electric motors frequently must operate under adverse conditions in an environment of excessive dust, dirt, moisture, or explosive gas or dust mixtures.

Motors are available with different types of enclosures, or housings, for use under specific operating conditions. Selection of the proper type of enclosure is important for protection of the motor and for personal safety.

Two general types of enclosures are available—open and totally enclosed.

Open enclosures may be drip proof or splash proof (fig. 5). A drip-proof enclosure protects the motor from falling liquid. It is designed for indoor use where the air is fairly clean and there is little danger of splashing liquid.

A splashproof enclosure protects the motor from splashing liquids. It is suitable for use in dairies and other places where equipment must be washed. It may be used outdoors, but must be protected from the weather (fig. 6.).

Totally enclosed motors are not ventilated internally and may be cooled by fan or by direct radiation and convection of heat through the case (fig. 7). They may be dustproof, waterproof, or explosion proof. They are designed for use under conditions of excessive dirt or moisture or where explosive gas or dust mixtures may be present, such as in feed or flour mills.

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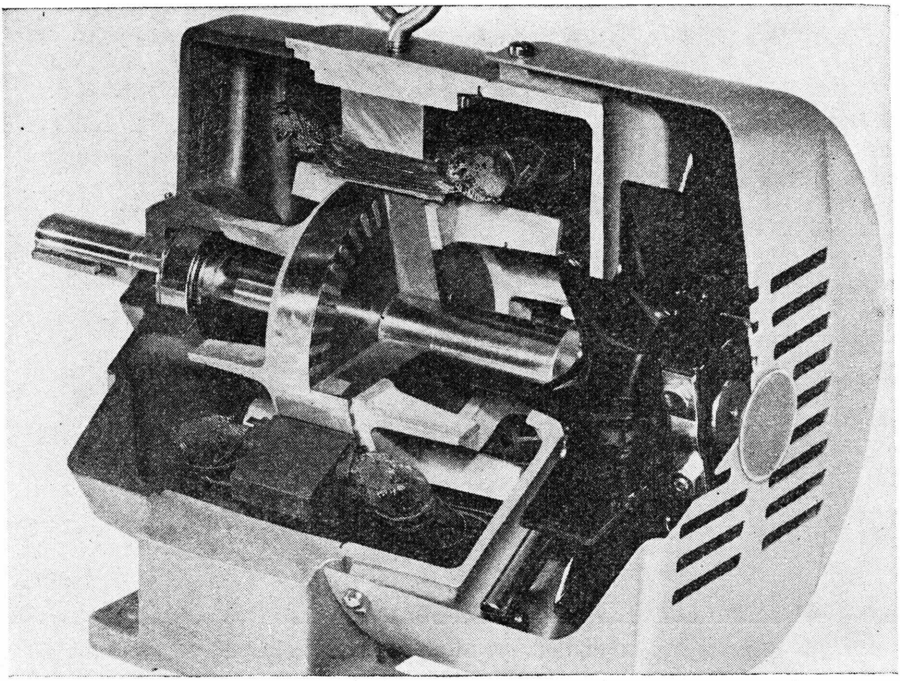

FIGURE 7.—Totally enclosed motors may be either nonventilated, disposing of heat by radiation, or fan cooled. This is a fan-cooled type.

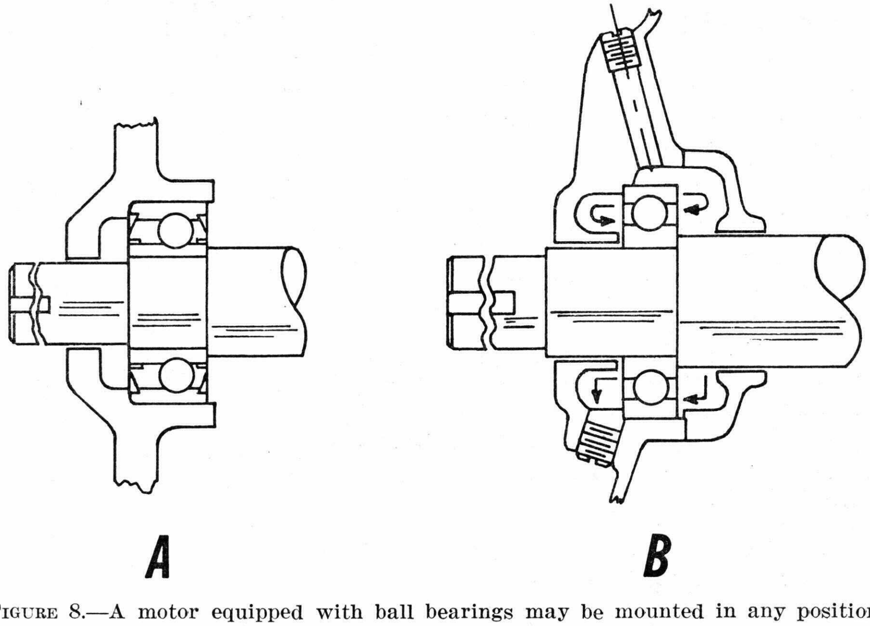

FIGURE 8.—A motor equipped with ball bearings may be mounted in any position. Ball bearings can take a small amount of axial thrust. Bearings may be either (*A*) the sealed type, requiring disassembly for relubrication, or (*B*) the type lubricated by grease gun.

Bearings

Electric motors are available with either sleeve or ball bearings (figs. 8 and 9). Sleeve-bearing motors usually cost less than ball-bearing motors.

Sleeve-bearing motors usually are designed to operate only in the horizontal position. They are oil lubricated, and the oil reservoir must always be toward the bottom of the motor.

Ball-bearing motors may be operated in a horizontal or vertical position. Ball bearings ordinarily used in electric motors are designed to absorb some thrust, but if the thrust load is high, special thrust bearings must be used.

Durability

The durability of a motor is indicated by its duty rating.

Motors are designed for "continuous" and "limited" duty. Continuous-duty motors will deliver rated horsepower for an indefinite period of time without overheating. Limited-duty motors will deliver rated horsepower for a specified period of time before overheating and will burn out if continuously operated at rated load.

A general-purpose motor should always be a continuous-duty type. Special-purpose motors are de-

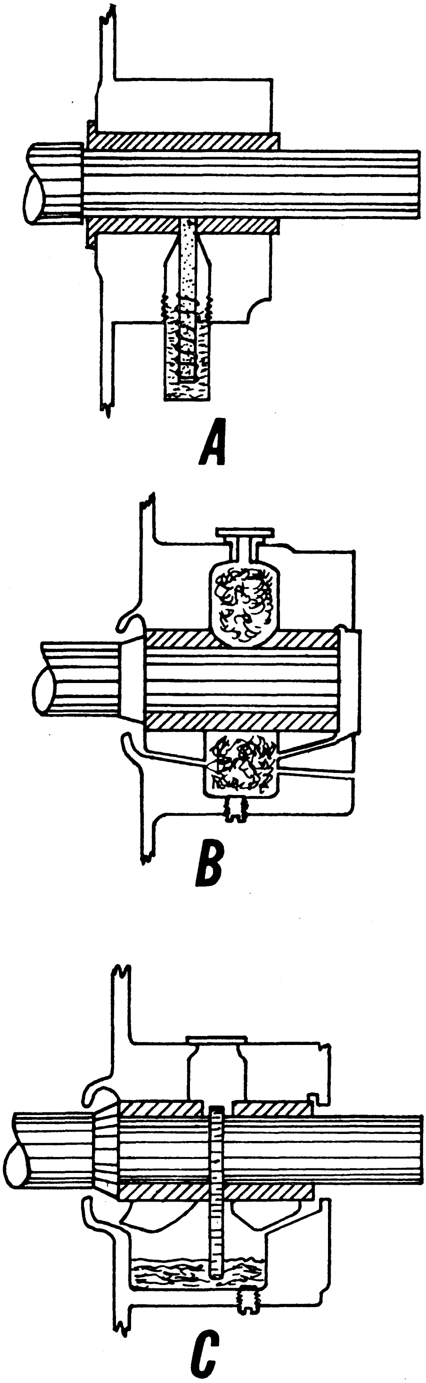

FIGURE 9.—Low-cost sleeve bearings are suitable for many motor applications. The motor shaft must be mounted horizontally with the oil reservoir underneath. Sleeve bearings will not absorb axial thrust. They may be lubricated by (*A*) oil wick, (*B*) yarn, or (*C*) oil ring.

signed for a particular job in which the specified time rating would not be exceeded. A silo unloader is an example. A limited-duty motor may operate the unloader satisfactorily for 30 minutes each period and the motor will cost less. If the operation period is extended to 1 hour, the motor will overheat and burn out prematurely.

Motor nameplates (fig. 10) carry three ratings indicating motor durability—motor code, service factor, and temperature rise. Motor code—designated by a letter on the nameplate—is indicative of starting current. The higher the locked-rotor kv.-a, the higher will be the starting current surge. Table 2 shows the various letter designations and the locked-rotor kv.-a. they represent.

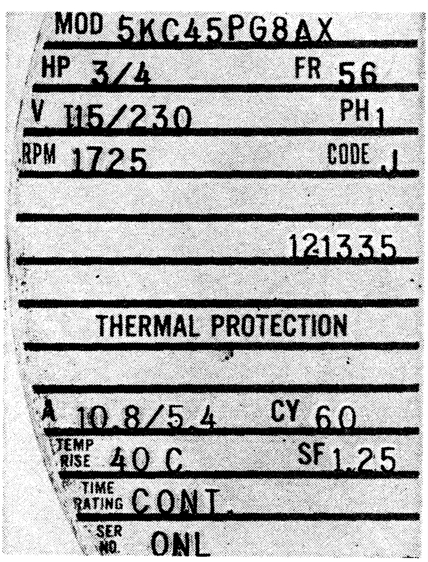

FIGURE 10.—The motor nameplate gives motor characteristics. The code designation, duty cycle, and temperature rise are important considerations in selecting a motor for a given job.

TABLE 2.—*Electric motor code designation for locked-rotor kv.-a. per horsepower* [1]

Code letter	Locked-rotor kv.-a. per horsepower [2]
A	0 to 3.15
B	3.15 to 3.55
C	3.55 to 4.0
D	4.0 to 4.5
E	4.5 to 5.0
F	5.0 to 5.6
G	5.6 to 6.3
H	6.3 to 7.1
J	7.1 to 8.0
K	8.0 to 9.0
L	9.0 to 10.0
M	10.0 to 11.2
N	11.2 to 12.5
P	12.5 to 14.0
R	14.0 to 16.0
S	16.0 to 18.0
T	18.0 to 20.0
U	20.0 to 22.4
V	22.4 and up

[1] Taken from the motor standards of the National Electrical Manufacturers Association.

[2] Locked-rotor kv.-a. per horsepower range includes the lower figure up to, but not including, the higher figure. For example, 3.14 is letter A and 3.15 is letter B. (Locked-rotor kv.-a. is equal to the product of line voltage times motor current divided by 1,000 when the rotor is not allowed to rotate—this corresponds to the first power surge required to start a motor.)

Service factor indicates the amount of overload the motor can tolerate.

Temperature rise is the extent—in number of degrees—to which motor temperature will exceed the surrounding air temperature at rated load.

The motor nameplate describes a motor's characteristics to the user. Figure 10 illustrates a typical motor nameplate and shows the important information.

Generally, a motor with a continuous-duty rating and a 40-de-

gree-centigrade temperature rise (72° F.) is a good motor capable of operating satisfactorily for an indefinite period of time if properly serviced and operated under normal conditions.

INSTALLATION

Proper installation of the electric motor is essential for satisfactory operation, maximum service, and personal safety. The installation and wiring should conform to that recommended by The National Electrical Code or any local code requirements which may be more restrictive.

Wiring

Motors perform best at rated voltage. Full-load voltage at the motor should be within 2 percent of the voltage at the meter and within 5 percent of the "nameplate" voltage rating of the motor.

Low voltage is a major problem in motor operation. It frequently results from voltage drop caused by inadequate wiring. Table 3 shows minimum allowable wire sizes for single-phase motors located various distances from the service entrance.

Wiring serving an electric motor or motors must be protected against short circuits by proper overcurrent protection. In addition, motors that are served from the main service panel or from branch circuits must have individual overload protection. Overload protection may be provided by means of circuit breakers, time-delay fuses, or thermostatic overload devices built into the motor. Figure 11 shows a typical motor installation and methods of providing overload protection.

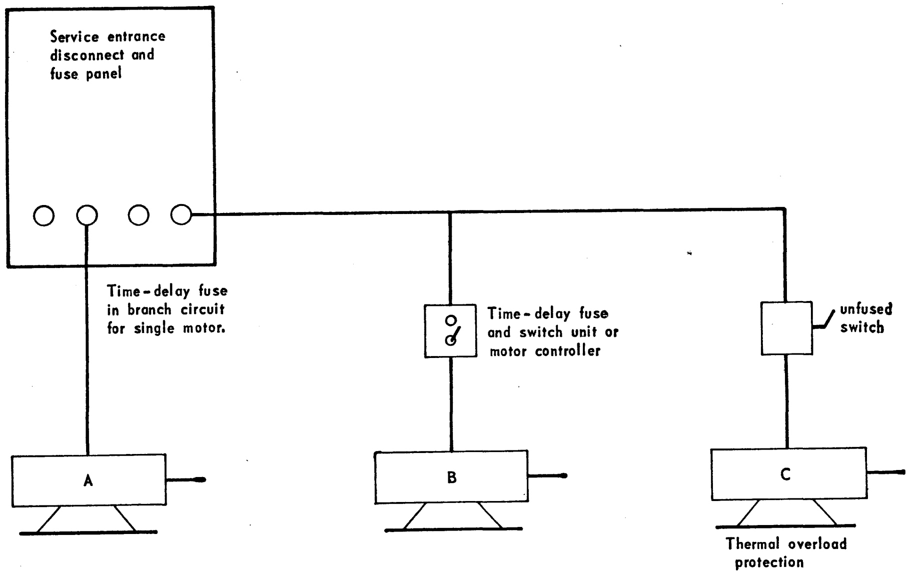

FIGURE 11.—Typical motor circuits which provide motor overload protection.

TABLE 3.—*Wire sizes for single-phase motors*

Volts	Full-load amperes	Nominal horsepower of motor	Distance in feet from service entrance to motor														
			0–20	30	40	50	60	80	100	120	160	200	250	300	350	400	500
			Wire size [1]														
115	4		14	14	14	14	14	14	14	14	14	12	10	10	10	10	8
	6	¼	14	14	14	14	14	14	14	12	12	10	10	8	8	8	6
	8	⅓	14	14	14	14	14	14	12	12	10	10	8	8	6	6	6
	10	½	14	14	14	14	14	12	12	12	10	8	8	6	6	6	4
	12		14	14	14	14	12	12	10	10	8	8	6	6	4	4	4
	14	¾	12	12	12	12	12	10	10	8	8	6	6	4	4	4	2
	16	1	12	12	12	12	12	10	10	8	8	6	6	4	4	4	2
230	3	¼	14	14	14	14	14	14	14	14	14	14	14	12	12	12	10
	4	⅓	14	14	14	14	14	14	14	14	14	14	12	12	10	10	10
	5	½	14	14	14	14	14	14	14	14	14	12	12	10	10	10	8
	6		14	14	14	14	14	14	14	14	12	12	10	10	10	8	8
	7	¾	14	14	14	14	14	14	14	14	12	10	10	10	8	8	6
	8	1	14	14	14	14	14	14	14	12	12	10	10	8	8	8	6
	10	1½	14	14	14	14	14	14	12	12	10	10	8	8	6	6	6
	12	2	14	14	14	14	14	12	12	10	10	8	8	6	6	6	4
	16	3	12	12	12	12	12	12	10	10	8	8	6	6	4	4	4
	25	5	8	8	8	8	8	8	8	8	6	6	4	4	2	2	2
	40	7½	6	6	6	6	6	6	6	6	4	4	2	2	1	1	0
	50	10	4	4	4	4	4	4	4	4	4	2	2	1	1	0	0

[1] Wire size is based on a 2-percent maximum voltage drop at full-load motor current for wire temperatures up to 167° F. Minimum size wire for overhead in air is No. 10 for spans of 50 feet or less. Minimum size wire for conduit cable or direct burial is No. 14, types R, T, TW, and RH. The maximum current-carrying capacity of conductors is reduced 20 percent in conformity with paragraph 430–22 of the 1960 National Electrical Code for single-motor branch circuits.

Mounting

Secure mounting and correct alinement with the load are essential for proper motor performance.

Locate the motor where it is readily accessible, but not in the way. If possible, locate it where it will not be exposed to excessive moisture, dust, or abrasive material.

Mount the motor on a smooth, solid foundation and fasten the mounting bolts tightly. If mounted on an uneven base or insecurely fastened, the motor may become misalined with the load during operation. This will throw unnecessary strain on the frame and bearings, causing rapid wear and overheating. Loose mounting bolts also cause vibration and noise during operation.

Connecting to the Load

Motors may be connected to the load by direct drive, chain and sprocket, or belt and pulley.

Direct drive may be used only when the motor and the driven equipment operate at the same speed. Use of a flexible coupling is recommended, and near-perfect alinement of motor shaft and driven shaft is required to prevent excessive wear of shaft bearings.

High-speed chain drives are used when a positive drive is necessary or when the torque required is more than a **V**-belt drive can transmit.

A **V**-belt drive is the most common and the easiest method of connecting a motor to the load.

Most motors available for farm use operate at about 1,800 r.p.m.; most equipment operates at much slower speeds. To compensate for the difference in operating speeds, you must use the proper size pulley on the driven equipment. To determine the load pulley size: Multiply the speed of the motor by the diameter of the motor pulley and then divide by the speed of the driven equipment.

Example

An ensilage cutter runs at 600 r.p.m. The motor operates at 1,800 r.p.m. and has a 6-inch pulley.

1,800 (motor speed) × 6 (motor pulley diameter) = 10,800.

10,800 ÷ 600 (equipment speed) = 18.

You would need an 18-inch pulley on the ensilage cutter.

Motor pulley and equipment pulley must be correctly alined to avoid excessive wear of belt and bearings (fig. 12). You can check pulley alinement by laying a straightedge along the outside edge of the pulleys (fig. 13).

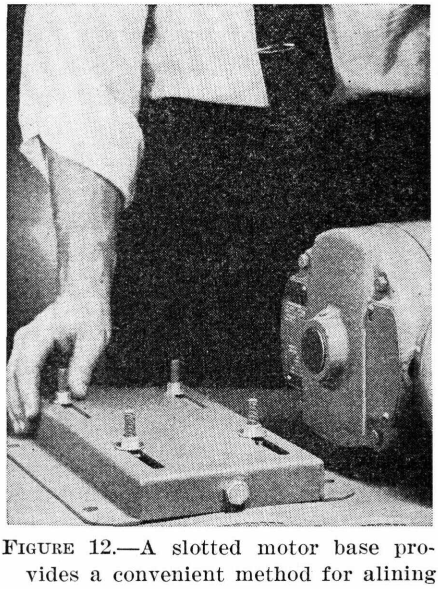

FIGURE 12.—A slotted motor base provides a convenient method for alining the motor with the load and for adjusting belt tension.

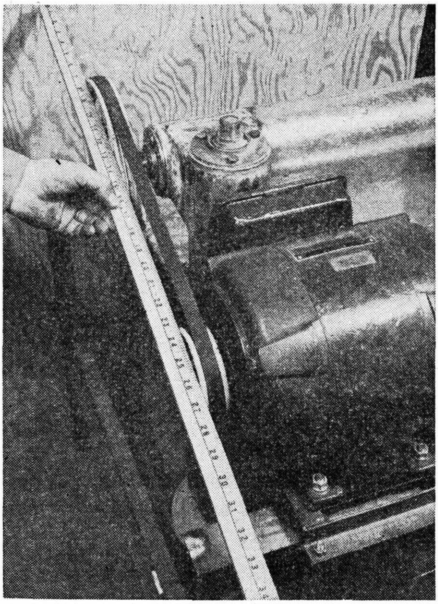

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FIGURE 13.—Aline the motor and load pulleys so that the belt is perpendicular to each shaft.

Proper belt tension must be maintained with a belt drive. If the belt is too loose, it will slip in the drive pulley, overheat, and wear out quickly. If it is too tight, it will cause excessive wear of belt and bearings. The belt should be snug in the pulley grooves, but not "bowstring" tight. Figure 14 shows proper belt tension.

Motor Wiring Connections

Single-phase, single-speed motors usually have two to six line leads, the number depending on the type of motor and on whether it is single or dual voltage.

Single-voltage split-phase and capacitor motors that are not reversible—direction of rotation cannot be changed—have only two leads.

Single-voltage split-phase and capacitor motors which are reversible have four line leads, two for the main winding and two for the auxiliary, or starting, winding.

Dual-voltage capacitor motors will have a minimum of six leads, four main winding leads and two auxiliary, or starting winding leads. For the low-voltage operation, all windings are connected in parallel to the line. For high-voltage operation, the main windings are wired in series and the auxiliary winding is connected to the center leads of the main winding and to one of the supply lines.

You can reverse a split-phase or capacitor motor—change the direction of rotation—by reversing the electric connections of either, but not both, the main or the auxiliary winding to the line (fig. 15). The terminals may be located on a terminal board or brought out of the motor frame into a terminal box

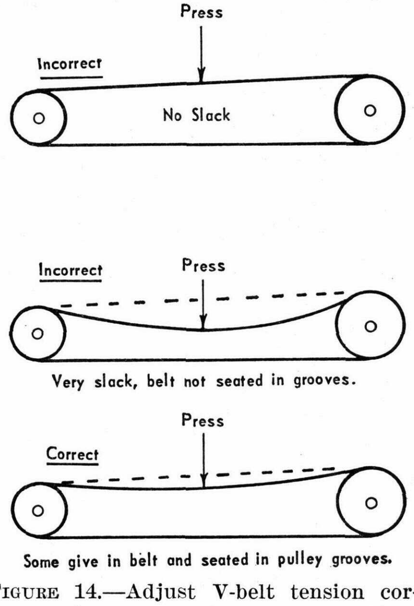

FIGURE 14.—Adjust V-belt tension correctly.

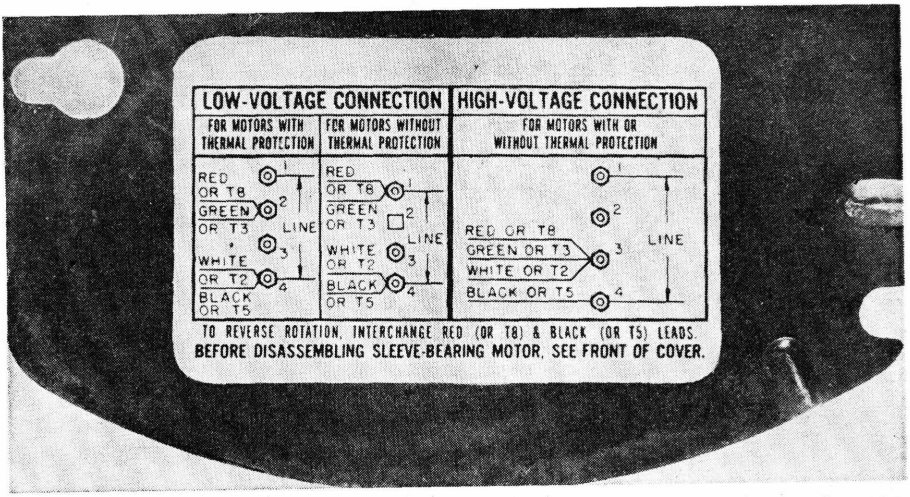

FIGURE 15.—The wiring diagram of a split-phase or capacitor motor shows which leads to interchange to reverse the direction of rotation.

as numbered leads. Be sure to follow the motor wiring diagram in making all connections.

Repulsion start-induction run and repulsion induction motors are usually dual-voltage motors with four winding leads. For low-voltage operation, the main windings are wired in parallel.

For high-voltage operation, the windings are wired in series. No change in rotor-brush connections is necessary for operation at either voltage.

You can reverse repulsion-type motors simply by rotating the brush ring to the alternate position (fig. 16). The brush ring of a repulsion-type motor is held in position by a locking screw or a spring clip; when released, the brushes may be rotated. The two brush positions are marked on the ring with an index on the frame. When the brush position is changed from one position to the other the direction of rotation is reversed.

Special-purpose or special-duty motors may differ in wiring and method of reversing direction of rotation. Consult the manufacturer's instructions.

MOTOR PROTECTION AND CONTROL

Protection

Motors must be protected against short circuits and overload.

An overloaded motor draws excessive current from the line; this causes overheating, which destroys insulation on windings and causes bearings to seize. (Maximum temperature at which a motor can operate depends on its construction and the type of insulation used on windings. A general-purpose motor is overheating if you cannot hold your hand on it for a few seconds.)

Motors may draw 3 to 12 times the amount of current for starting

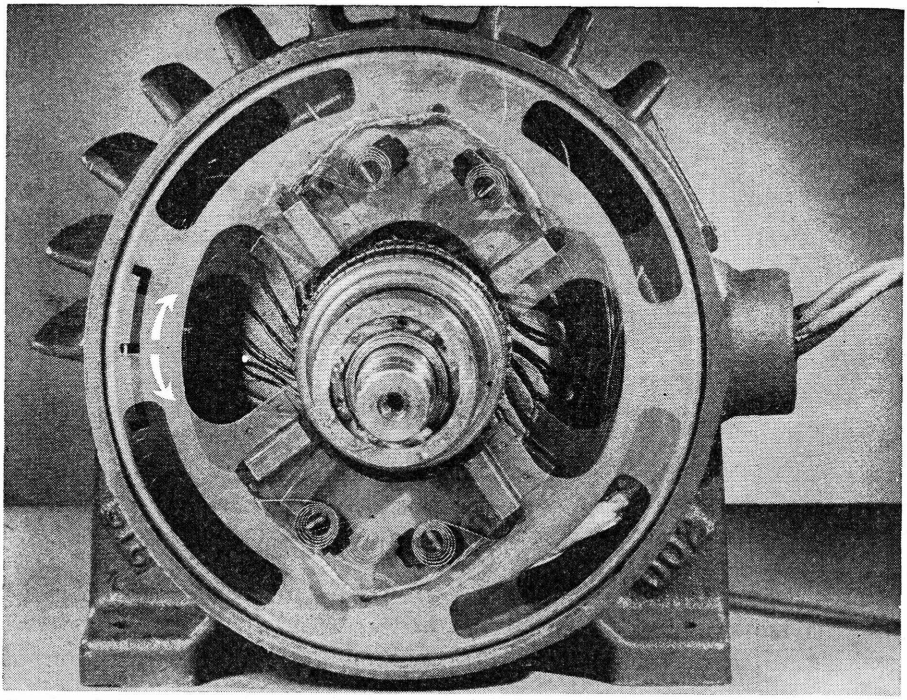

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FIGURE 16.—Most repulsion-induction motors are reversed by rotating the brush ring (as shown) to the alternate position. Double arrow indicates rotation.

than for running at full load. Short-circuit protection devices must be able to carry this high current for a short time.

Ordinary circuit fuses do not protect the motor; they protect the circuit wires only. Therefore, additional motor protection is needed.

Time-delay fuses (fig. 17) afford both short-circuit and overload protection. A short circuit almost instantly melts the fusible link in the fuse, opening the circuit. In case of overload, heat developed in the second element of the fuse weakens a eutectic solder connection, permitting a spring to break the connection (fig. 18). Time-delay fuses must be of the proper size to protect the motor.

Motor starter switches, both manual and electromagnetic, are available with built-in overload protection. The thermal overload relay is the most commonly used protective device in the switches (figs. 19 and 20). A thermal overload relay is usually one of two types—bimetallic or eutectic solder. The bimetallic type may be temperature compensated. If the overload relay is not temperature compensated, install the combination switch-relay unit where it will be under the same operating conditions as the motor.

A thermal overload switch built into the motor affords the best protection against overload (fig. 21). The switch can open the line directly on fractional horsepower motors. For larger motors, a relay

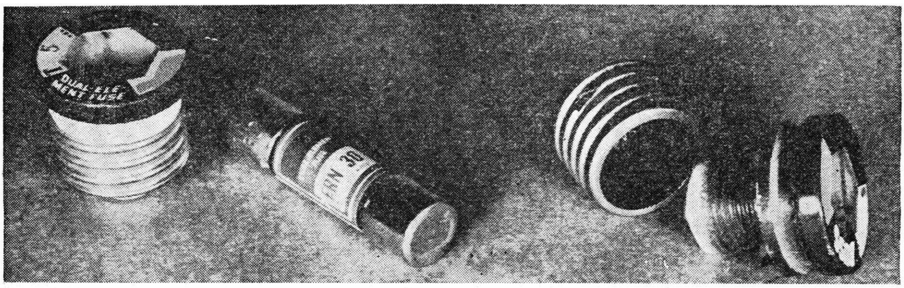

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FIGURE 17.—Time-delay fuses of the proper size should be used to protect motor circuits. The fuse on the left can replace a common plug fuse on old installations. The middle fuse is a cartridge fuse and should be used in 230-volt circuits. The fuse on the right when placed in a fuse socket cannot be replaced with any fuse except one of equal rating.

may be needed if the thermal unit cannot handle the larger current. Built-in thermal protective units may be automatic-reset or manual-reset type. A manual reset is recommended for general-purpose use; you can correct the cause of overload before restarting the motor.

Control

Control switches (fig. 22) for electric motors must be able to withstand high in-rush starting current and the arcing that occurs when the circuit opens. "Quick-make, quick-break" switches equipped with "arc quenchers" are used and are rated in horsepower and voltage.

T-rated tumbler-type light switches should not be used to control electric motors. They can withstand the high in-rush current, but not the arcing. Such switches not equipped with "arc quenchers" usually burn out quickly.

A magnetic motor starter is the best method of controlling a motor. It should be used for all motors larger than 1 horsepower and is essential in automatic control systems.

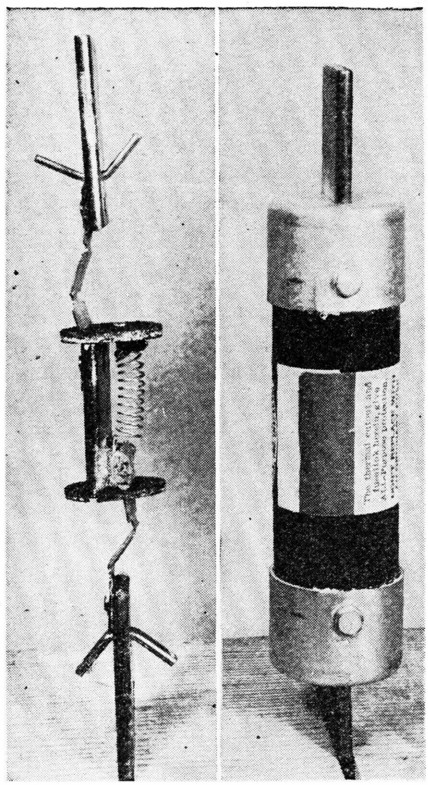

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FIGURE 18.—Time-delay, two-element fuses. The stripped unit on the left shows the two elements, one for short-circuit protection (fusible links) and one for a brief overload (the spring-loaded eutectic solder link in the center of the fuse).

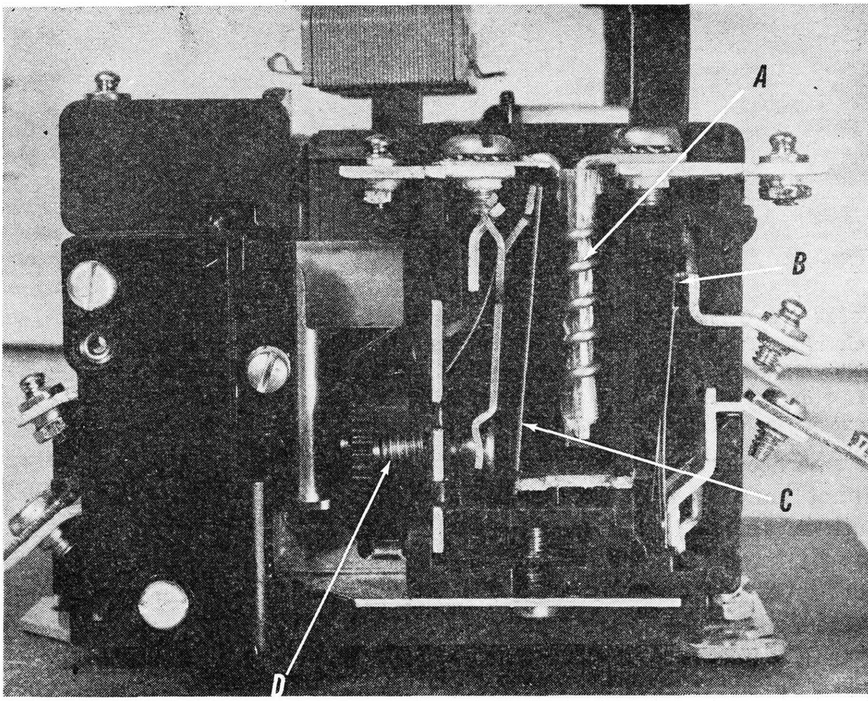

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FIGURE 19.—The thermal overload relay may be the bimetallic (shown above) or eutectic solder type. It is the most often used protective device for manual and electromagnetic starter switches. *A*, Heater; *B*, interlock contacts; *C*, bimetallic strip; *D*, compensation adjustment.

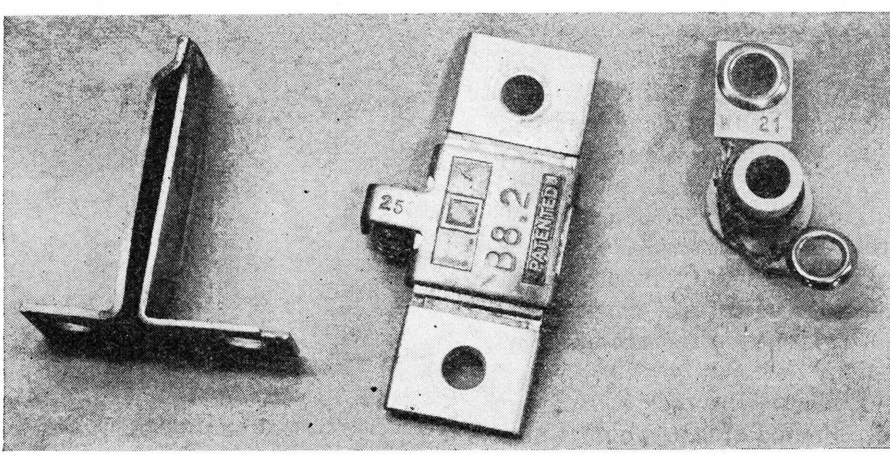

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FIGURE 20.—Thermal overcurrent relay elements are resistance units that generate heat in proportion to the current flowing through them. On the left is a heater for a bimetallic overcurrent relay. In the middle is a eutectic solder unit. On the right is a heater used in a small manual starter switch.

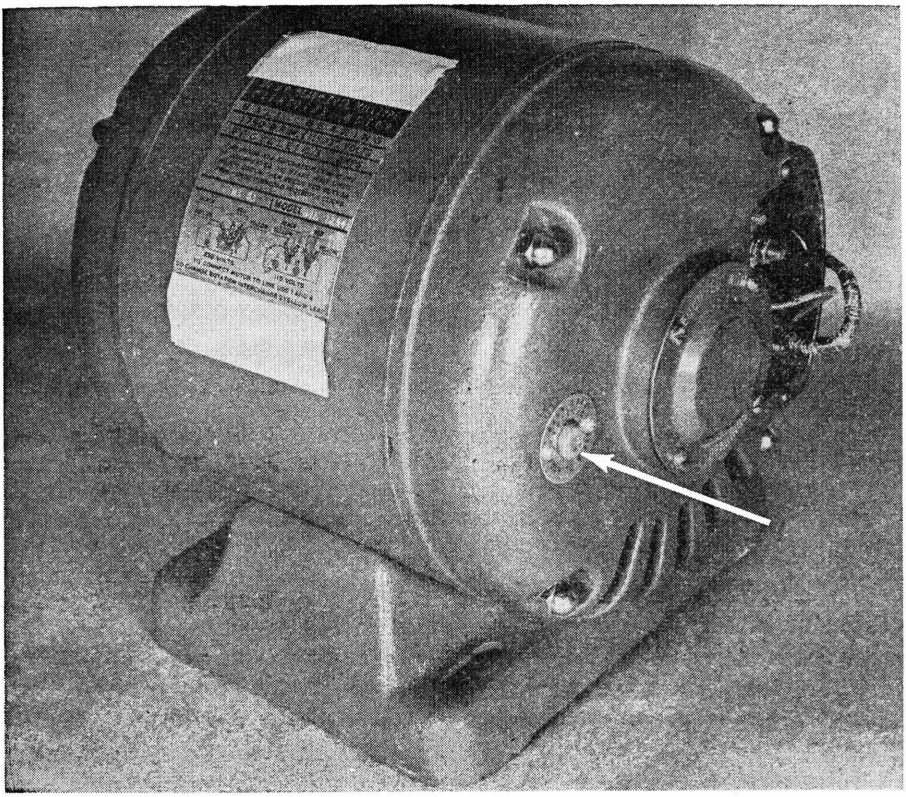

FIGURE 21.—A thermal overload switch which is built into the motor is an excellent method of protecting the motor from overload conditions. Arrow points to reset button.

SERVICING

A well-made electric motor, properly installed, requires less maintenance than many other types of equipment. However, for best and economical performance, a motor will require periodic servicing.

Periodic Servicing

Perform these service operations at least once a year—and more often if the motor operates under severe heat, cold, or dust conditions:

- Remove dust and dirt from air passages to insure proper cooling. Plugged air passages, or a coating of dirt on a totally enclosed motor, will cause the motor to overheat under normal operation.
- Check bearings for wear. Excessive side-play or end-play may cause the motor to draw higher starting current and develop less starting torque.
- Lubricate with the type and amount of lubricant specified by the manufacturer. Do not over-lubricate. Too much lubricant is just as bad as too little.
- Check wiring for frayed or bare spots. Repair or replace as needed.
- Clean starting-switch contacts of split-phase and capacitor motors

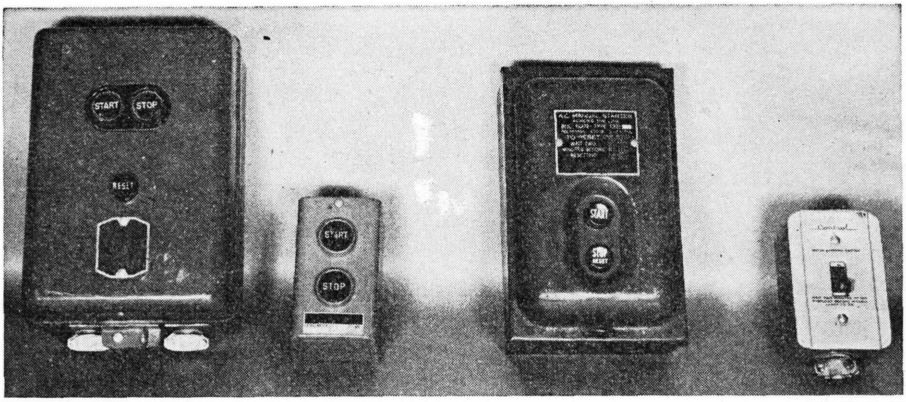

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FIGURE 22.—The correct motor starter switch provides the best protection for your motor. *Left to right:* A magnetic motor starter with self-contained push-button switches; a push-button start-and-stop station for remote installation with a magnetic starter; a manual starter switch for integral horsepower motors; and a manual switch for fractional horsepower motors.

and commutator and brushes of repulsion motors. Use very fine sandpaper, *not emery cloth.* Replace worn brushes. Be sure that the brush-lifting and shorting-ring action works smoothly.

• Be sure that the motor shaft turns freely. Tight or misalined bearings will cause the motor to overheat.

• Check belt pulleys to be sure that they are secure on their shafts. Aline belts and pulleys. Improper alinement causes excessive wear of belts and pulleys. Check belt tension. Replace belts if they are badly worn.

Repair

If properly installed and serviced, an electric motor should give trouble-free service for many years. However, a motor will occasionally give trouble and may even fail to operate. Some repairs will require the services of an experienced electrician or motor serviceman; others can be made by the operator.

Table 4 lists various motor troubles, their causes, and repairs.

Caution: Do not attempt to make changes or repairs on electric motors until they have been disconnected from the circuit.

TABLE 4.—*Troubles in single-phase motor operation, causes, and remedies*

MOTOR FAILS TO START

Cause	Remedy
Fuses blown	Examine fuses, switches, and connections between motor terminals and points of service. Also look for broken wires and connections.
Switch open	
Broken connections	
No voltage on line	
Poor connections	Examine and repair connections.
Wiring too small	Increase size of wire.
Overloaded service	Notify power company.

MOTOR FAILS TO START—Continued

Cause	Remedy
Not sufficient torque	Reduce load and check for low voltage.
Bearing linings worn so that rotor rubs on stator.	Renew sleeves, center rotor in stator bore.[1]
Bearings too tight, or lack of proper lubrication.	Adjust and lubricate bearings. Check end bells for alinement.
Broken connections	
Burned-out windings, indicated by smoke and local heating.	Locate and repair.[1]

EXCESSIVE HEATING

Overloaded	Reduce load.
Poor or broken insulation	
Broken connections	Test and repair.[1]
Grounds or short circuits	
Wrong connections	Check with wiring diagram of motor.
Worn bearings	Test with feeler and renew or repair bearings; check end bells alinement.[1]
Rotor rubs on stator	
Bearings too tight	Renew bearing sleeves.[1]
Belt too tight	Slacken belt.

EXCESSIVE VIBRATION

Unbalanced rotor	Have rotor balanced.[1]
Worn bearings	Replace sleeves.[1]
Misalined with load	Aline motor shaft with load shaft.
Loose mounting bolts	Tighten.
Unbalanced pulley	Have pulley balanced or replace with new.
Uneven weight of belt	Get new belt.

EXCESSIVE SPARKING WHEN STARTING

Dirty or rough commutator	Clean and sandpaper.[1]
Worn or stuck brushes	Renew or adjust brushes.[1]
High or low commutator bars	Turn off in lathe.[1]
Excessive sparking at one place on commutator.	Check for shorted rotor winding or loose winding to bar connection.[1]
High mica	Undercut mica.[1]
Overloaded	Lighten load.
Open rotor or stator coil	
Grounds	Inspect, test, and repair.[1]
Poor connections	
High or low voltage	Notify power company and inspect wiring.

EXCESSIVE SPARKING AT NORMAL SPEED

Dirty short-circuiting device	Clean with acceptable solvent—do not use carbon tetrachloride.
Governing mechanism sticks or is badly adjusted.	Readjust mechanism.[1]
Worn brushes	Replace.

EXCESSIVE SPEED

Dirty short-circuiting device	Clean with acceptable solvent—do not use carbon tetrachloride.
Governing mechanism sticks or is badly adjusted.	Readjust mechanism.[1]

[1] These repairs should be made by an experienced electrician.

LOW SPEED

Cause	Remedy
Overloaded	Reduce load.
Dirty or rough commutator	Clean and sandpaper.[1]
Badly worn brushes	Replace with new brushes.[1]
Brushes not properly set	Adjust brushes.[1]
Brushes stuck	Clean and adjust.
Wrong or bad connections	Check for proper voltage connections and repair.
Low voltage	Reduce load.
Overloaded line	Increase size of wire.[1]
Wiring too small	

MOTOR HUMS BUT WILL NOT START

Cause	Remedy
Worn brushes	Renew brushes.
Starting winding switch does not close	Clean or replace and lubricate if needed.
Brushes stuck in holder	Adjust brushes.[1]
Brushes not properly set	Check with marks on frame.
Motor overloaded	Lighten load.
Open rotor or stator coil	Test and repair.[1]
Defective starting capacitor	Replace.[1]
Worn bearings	Replace bearings.[1]
Burned or broken connections	Test and repair.[1]
Overloaded line	Notify power company and check wiring.
Low voltage	
Poor connections	Repair.

MOTOR WILL NOT START WITH ROTOR IN CERTAIN POSITION

Cause	Remedy
Burned or broken connections	Inspect, test, and repair.[1]
Open rotor or stator coil	

SLOW ACCELERATION

Cause	Remedy
Dirty or rough commutator	Clean and sandpaper.
Worn or stuck brushes	Renew or adjust.[1]
Brushes not set properly	Adjust brushes.[1]
Overloaded	Lighten load.
Poor connections	Test and repair.
Low voltage	Lighten line load or increase size of line wire.[1]
Overloaded line	

RAPID BRUSH WEAR

Cause	Remedy
Rough commutator	Smooth with fine (00) sandpaper. (Do not use emery cloth.)
High or low bars	Turn off in lathe.[1]
High mica	Undercut mica.[1]
Overload	Lighten motor load.
Poor connections	Test and repair.
Low voltage	Increase size of wire.[1]
Commutator not round	Test and repair.[1]

[1] These repairs should be made by an experienced electrician.

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